Resource Guide

Internet Broadcasting

Explore the Potential

Inktomi

Inktomi®

1. Executive Summary

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Streaming media is the next revolution in communications. There are over 3500 producers broadcasting on the Internet, and, according to analysts, streaming media traffic is doubling every six months. And this is just the tip of an enormous—and growing—opportunity on the horizon. Analyst forecasts for the 2004 Internet broadcasting market range from a "conservative" estimate of $22B to a bullish prediction of $40B.

The presence of both push and pull forces is propelling the success of the Internet broadcasting industry. The push comes from streaming media producers—veterans and newcomers alike—who want to reach worldwide audiences and create new, interactive forms of program content. The pull comes from a consuming public, corporations, and advertisers eager to spend money on subscriptions, pay-per-view, advertising, and sponsorships.

The size and strong momentum of this fast-growing market contain ample opportunity for all service providers, whether operating in the Internet's core or at its edges. An increasing percentage of traffic in content distribution networks (CDNs) is streaming media, and savvy service providers are already forming business relationships with one another—and with content producers. At the edges, access providers are finding streaming media presents equally lucrative opportunities as a catalyst for upgrading users to broadband and as a fertile field for highly-differentiated, value-added services.

The Internet is the ideal next-generation broadcast medium because it provides powerful capabilities that are not possible with other broadcast technologies. For example, the Internet affords a reach unrestricted in time and space for both mass-appeal and target/niche audiences. And the Internet is unique in its potential for interactivity and program personalization.

The Internet today, however, handles streaming media only on a limited scale with regard to both audience size and duration of programming. The underlying cause is that the Internet was not designed for streaming media content and any attempt at a large-scale event makes its limitations painfully obvious.

Many alternatives have been proposed to make large-scale, profitable Internet broadcasting a reality, but, to-date none have delivered the full suite of capabilities necessary. Therefore, what the industry needs is a robust end-to-end architecture designed for reliability, scalability and manageability.

Inktomi is the first company to deliver the Internet infrastructure solution needed to transform the Internet into a "Prime Time" broadcasting medium.

Inktomi developed an architecture that layers multicasting end-to-end across a routed internetwork at the application layer, rather than the networking layer. An overlay architecture applied atop the existing IP-routed infrastructure and equipped with application-level multicasting makes Internet broadcasting affordable to deploy, operate, upgrade, and expand. In addition, an overlay approach is flexible and extensible, supporting evolving needs and a full spectrum of value-added services, including the ability to "peer" up and down the delivery chain at the application layer. Lastly, an overlay architecture provides the reliability, quality and manageability necessary to the success of the Internet broadcasting business.

With its overlay architecture and enabling technology, Inktomi is now in a position to move Internet broadcasting to the next level of performance and profitability. As a total solution for both live and on-demand Internet broadcasting, Inktomi's media products let any service provider begin to build a successful media distribution business today. And with its extensible platform — implemented entirely in software — Inktomi customers get full investment protection as new capabilities are added and benefit from third-party applications developed to enhance the platform.

Finally, the platform satisfies both the revenue-generating and cost-saving needs of all parties involved in the Internet broadcasting business. This includes the ability to support emerging business models based on audience response, subscriptions, pay-per-view, customized ad insertion, and other value-added service options, along with the ability to conserve bandwidth through intelligent application-level multicasting.

The remainder of this document is organized into four subjects. *The Streaming Media Revolution* in Chapter 2 provides background information and highlights the opportunities available for service providers. Chapter 3, *Issues in Internet Broadcasting*, outlines the inherent limitations and the enabling technologies that serve as the departure point in the search for an enduring solution. *A "Prime Time" Internet Broadcasting Architecture* (Chapter 4) lists the business and technical requirements that a viable design must meet, and describes an architectural approach that fully satisfies every one. The fifth and final chapter, *The Media Distribution Network*, introduces Inktomi's solution — both the platform and the products — and describes how this innovative solution works end-to-end to make Internet broadcasting a profitable business.

Additional information on Internet broadcasting and related topics — from streaming media basics to content peering specifics — is available from Inktomi at **www.inktomi.com**.

2. The Streaming Media Revolution

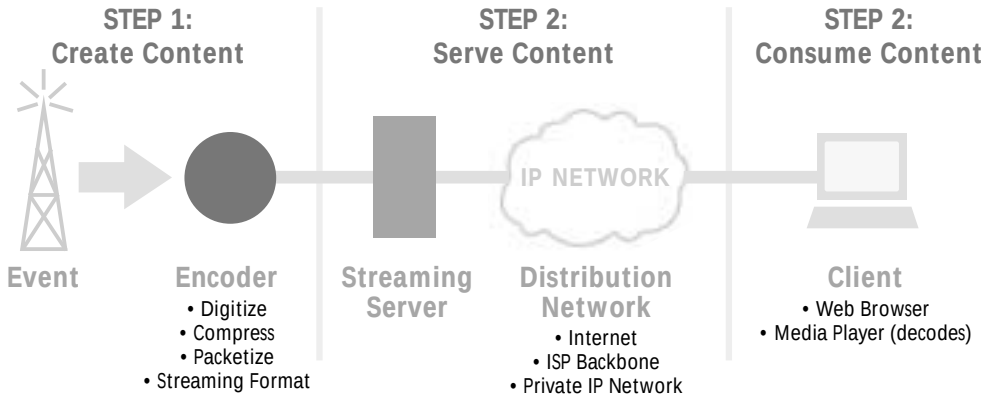
In this section, we will explain a few terms for you, explain why the Internet excels as a broadcast medium, and outline the opportunity created by the streaming media revolution.

Because there is some confusion in the industry and difference of opinion regarding meanings, we will define a few terms for you before proceeding. "Streaming media" is the digitized version of how people normally communicate — sight (video) and sound (audio) — and is part of the natural progression for digital content. Beginning as the printed word, content migrated to text and graphics with the advent of desktop publishing systems, and evolved later to animation and other so-called "rich media" on the Web.

Streaming Media Building Blocks

Streaming media involves four distinct building blocks, as shown in the diagram:

- The ***Encoder*** digitizes the program (the media) in a special, compressed format and with special sequencing for transmission (streaming) via the network. Streams can be encoded for different data rates (e.g. 56 kbps, 128 kbps or 1.5 Mbps), which allows users to view content optimized for their Internet access method.
- The ***Server*** is the equivalent of the broadcast station. Servers "inject" or "feed" programming both in to and out of the network.
- The all-important ***Network*** — in this case, the Internet — is the subject of this document, and is covered in-depth in the next chapter.
- Finally, the ***Client*** is a special application that runs on a PC or other specially equipped device such as a television set-top box or a handheld device.



Encoders, servers and clients utilize one of three popular formats; the network, ideally, is able to handle all three:

- RealSystem from RealNetworks
- Windows Media Technology from Microsoft
- QuickTime from Apple

The *media* portion of streaming media exists in a wide variety of forms, including music, news, television programming, movies, documentaries, training videos and more. The terms "rich media" and "multimedia" are often used to emphasize the inclusion of both audio and video, with both being digitized — again in an assortment of formats. This document uses the term *media* to encompass any audio/video material or programming.

The *streaming* portion of streaming media has a unique meaning in the context of networks like the Internet and can be compared to playing a video tape — broadcasting via the Internet must be performed continuously and in real-time, hence the notion of a stream or continual flow.

Why Broadcast via the Internet?

The Internet offers many unique capabilities that make it superior to traditional broadcast methods. Together, they make a compelling case for broadcasting via the Internet.

Unrestricted reach – There are an estimated 300 million regular users of the Internet today, and most analysts believe that one day the entire developed world will have Internet access. However, the Internet's advantages go beyond sheer numbers. No other medium can reach such a huge audience with just a single feed — or a single ad. With the Internet, there are no physical limitations, like those traditional broadcasters face with line-of-site antenna transmissions.

Niche audiences – The Internet makes it cost-effective to reach small-but-viable niche or special interest audiences. There is often not a critical mass of specialty audiences in Tokyo, London, New York, or any other single area to support broadcast solutions that are restricted in time and space. However, there often is a large enough audience *worldwide* to make specialty programming profitable through audience aggregation, syndication, pay-per-view, subscriptions, and advertising.

Audience interactivy – Other means of broadcasting are strictly one-way. Even cable, which does have the technological potential to be interactive, has been implemented as one-way medium. The Internet, by contrast, was designed as a full communications infrastructure: two-way, *to* and *from*. The Internet's interactivity gives the audience a direct feedback channel to the producer, which can even be used to take instantaneous polls or surveys.

Streaming Media

Programming personalization – The interactivity of the Internet lends itself to some programming possibilities that are not possible with traditional broadcasting. For example, users are able to "control" viewing options, including camera angles or instant replays during a sporting event. Internet users will be able to go "off line" (off the mainline story, that is) to companion programming in the form of a sidebar or an in-depth analysis, or buy a product they saw used or advertised — then rejoin the regular program if they wish.

Programs on-demand – Pay-per-view, the nearest thing to on-demand programming today, has specific start times, as do live events. However, imagine being able to start a movie whenever *you* want — just like with a videotape but without the trip to the rental store. Internet users will even be able to rewind or fast-forward if desired. Miss the start of a live event? No problem with the Internet. Just tune in to the on-demand version, the end of which is still being recorded as you start to experience it from the beginning.

Broadcast empowerment – No other medium is as unrestricted or ubiquitous as the Internet. Therefore, for the very same reasons that text and graphic content were created for the Web, organizations are now creating streaming media content for the Internet. Naturally, numerous restrictions may still apply to the nature of the content, including those involving contracts, copyrights, or international issues. But as a broadcast medium, the Internet is wide open.

Business model flexibility – The Internet also eliminates some of the obstacles that have constrained broadcasting business arrangements. With virtually unregulated and unrestricted access to the Internet's power and presence, players are free to pursue both traditional and innovative business models.

Streaming + Media = Opportunity

The ability to broadcast streaming media live and on-demand creates tremendous opportunities for Internet service providers, backbone and content service providers, and even the producers of media content around the globe.

Analysts expect that both business-to-business applications and entertainment will drive the Internet broadcasting industry. According to the Internet Research Group, "streaming media will provide multiple killer apps enabled by increased broadband access." Current examples include traditional and enhanced versions of TV/radio programming, news, movies, sporting events, interactive gaming, music and the arts, specialty or niche events and programming, and more. In addition, as the entertainment industry has forged ahead, other applications, including business and educational uses, have not been far behind. Examples include distance learning, training, corporate communications and streaming news broadcasts.

The enthusiasm for getting all this programming on-line continues to build for a simple reason: producers, advertisers, corporations, and service providers alike see a financial opportunity. Analyst predictions of the market's size vary (see the sidebar titled *The Internet Broadcasting Iceberg*), but all are unanimous that the market will be huge. And the reason is simple: The ability to reach a worldwide audience with a single feed is unprecedented in its power.

The Internet Broadcasting Iceberg

The Aberdeen Group predicts that Internet broadcasting will be a $40B marketplace in 2004, which would make it about as large as either the broadcast or cable television industries are in the U.S. today. Other analysts offer somewhat more conservative predictions. Both Perey Research and US Bancorp Piper Jaffray place the size of the 2004 market at a little over half of Aberdeen's estimate, or $22B. Deutsche Banc Alex Brown forecasts the five-year opportunity to be $25B.

Regardless of the estimate, savvy service providers know this beginning is just the tip of an enormous Internet broadcasting iceberg forming below the horizon. Dataquest calculates that the volume of streaming media traffic is already doubling every six months. And consider this: Paul Kagan Associates values the current entertainment industry at just over a half *trillion* dollars! The computer networking industry has never encountered numbers this large before, but that's Hollywood!

The presence of both push and pull forces for broadcasting streaming media via the Internet ensures exciting times ahead. The *push* to is coming from producers who want to reach broader audiences more readily and create new forms of program content. The *pull* is coming from a consuming public anxious to take advantage of the power and promise of streaming media. Together, these forces set the stage for rapid and unprecedented growth in Internet broadcasting.

RealNetworks estimates there are now over 100 TV stations and 3500 radio stations on the Web, including 41 of the top 45 cable and broadcasting companies. The major networks — including CNN, ABC, NBC, CBS and Fox — are among the leaders, which legitimizes the endeavor and backs its success with enormous resources. And just as with traditional broadcast programming, advertising will help pay the way for much of the media streamed on the Internet. By 2002, over 250 million people will view events broadcast live or on-demand on the Internet, according to the International Webcasting Association.

Streaming Media

The size of this fast-growing market, based on even the most conservative estimate, contains ample opportunity for all service providers, whether operating in the Internet's core or at its edges — or in both of these important domains.

The Internet's backbone already recognized the importance of differentiating content with the advent of content distribution networks (CDNs). CDNs combine data communications, servers and storage to improve Web access performance. In a CDN, content is distributed from an origin server to the edges of the Internet, and from there it is delivered to local users. These content-aware infrastructures have grown in lock-step with the variety and growth of material available on the Internet. Some providers deploy CDNs exclusively for their own access subscribers; others offer CDN-based services for other service providers — the access-only Internet Service Providers (ISPs). Either way, they will benefit from the projected growth of streaming media content and the need to deliver high quality broadcasts.

The access ISP, at the edge of the Internet, also has an enormous opportunity. Access ISPs control the relationship with subscriber customers or the audience for streaming media that producers and advertisers want to reach. In other words, the edge is where money will begin to change hands. Users accessing subscription-based services or pay-per-view offerings pay their *local* ISP. Local advertisers do the same.

Service providers who offer Internet broadcasting services can establish competitive differentiation, attracting new customers and building incremental revenue from existing subscribers through high-value, high-margin streaming media services. In addition, streaming media is a catalyst for migrating users from modems to broadband access over digital subscriber line (DSL) or cable. Savvy service providers recognize the potential of this market, which is why many have already jumped on the Internet broadcasting bandwagon.

The streaming media revolution will bring about quite a few changes in the Internet and place a potential burden on what is already a fully-loaded infrastructure. More broadband users. New business models. New CDNs and enhancements to existing ones. And not just for a single event or program, but for thousands of media streams reaching millions of viewers. It's a lot to ask of the Internet. Is it up to the task?

Show Me the Money

The "monetizing" of streams has already begun as money changes hands in both traditional and innovative ways. Here are just a few examples:

- Producers are charging consumers for subscription or pay-per-view services.
- Advertisers are paying producers for the privilege of sponsoring programming. The ads might reach a broad audience or be targeted quite narrowly based on specific demographics.
- CDN providers are charging producers and access ISPs at both ends of the feed, but not necessarily at the same time.
- CDN providers are charging one another when they exchange streaming media content — so-called "content peering."
- Access ISPs are charging consumers directly, getting a cut of the producer's subscription and pay-per-view charges, and growing advertising revenues with "a word from your local sponsor."
- And some service providers are even becoming streaming media content *producers* for either licensed or original content!

3. Issues in Internet Broadcasting

This section outlines the limitations inherent in the design of the Internet and describes the current approaches to solving the issues restricting Internet broadcasting today.

The enormous potential of streaming media on the Internet is being affected by some sobering realities. As mass audience Webcasts occur with increasing frequency, limitations inherent in the underlying Internet infrastructure have become apparent:

- The Internet protocol (IP) was designed as a point-to-point or "unicast" solution—far from ideal for broadcasting live events to large audiences.
- The Internet is a "best effort" network with no assurance of end-to-end quality or service levels for streaming media applications.
- The Internet is a federation of networks with no single party in control, leaving the many service providers with little or no means for infrastructure-wide management of streams.

Today's unicast-based Internet is one-to-one end-to-end. This unicast design serves traditional Web content (text and graphics), and even on-demand streaming media well. In fact, because the edge of the Internet has a one-to-one topology, individual users are best served by the analogous point-to-point, unicast mode of communications. The problem with unicast is that it fails to scale in the backbone and the core of the Internet can only handle so many point-to-point transmissions before it becomes overloaded.

Additionally, traditional Web content is quite tolerant of best effort service in the loosely-controlled inter-domain environment of today's Internet. Live streaming media, by contrast, is much more demanding and does not tolerate latency, which must be managed end-to-end.

None of the Internet's inherent limitations is insurmountable. There are new technologies advancing the state-of-the-art, and this chapter explores several that should have a significant role to play in Internet broadcasting.

Pieces of the Internet Broadcast Puzzle

Because streaming media is different from other forms of content on the Web, the broadcasting of media streams via the Internet demands a different approach. Highlighted here are some of the key technologies that have "supporting roles" in the end-to-end, global Internet broadcasting infrastructure. Each provides a piece of the puzzle, and together, they form a fairly robust solution for on-demand streaming media content.

IP Multicast – IP Multicast allows content to be transmitted simultaneously and efficiently in a one-to-many form of communication, which helps overcome some of the limitations of unicast. And while IP Multicast works well enough and is now a standard feature of most IP routers, the majority of ISPs have avoided this technology on a large scale. Why? Because deploying, provisioning and managing router-based multicasting is extraordinarily difficult. In addition, there are no end-to-end security, accountability or serviceability provisions with IP Multicast. For example, the content producer has no visibility into audience response, either individually or in the aggregate. Finally, content peering is so complicated with a lack of inter-domain multicast routing and end-to-end policy controls as to be commercially infeasible, at best, and virtually impossible, at worst. For these reasons, the role of IP Multicast is expected to remain intra-domain; that is, within a single service provider's network.

Caches – Caches serve to minimize duplication of traffic in the backbone, relieving much of the current congestion, and in doing so help deliver better response times to users. Caches work by capturing content at the edges of the Internet as it passes by on the way to local users. The freshly-stored content is then served up again, locally, to subsequent users. Alternatively, content can be "pushed" outward in a proactive fashion from its source to load or refresh designated caches across the Internet. Pushing should be considered a form of broadcasting because it distributes content to multiple locations simultaneously. The bandwidth savings are real and potentially significant for on-demand content of all types, including streaming media. But caching is not appropriate for live events.

Internet Broadcasting

Load Balancing – Just as the Internet's backbone becomes overwhelmed by too many point-to-point transmissions, so too can the target server of popular content. Servers can scale to handle thousands of individual sessions, but the expansion eventually reaches a point where it becomes too cumbersome — and costly. The premise behind load balancers is that when a single server cannot handle a large load, it becomes advantageous to "front-end" a bank or farm containing many servers to achieve scale. These devices have various names, including Layer 4 or Application Layer switches; all operate in the LAN at a single site, and a few now have WAN or multi-site capabilities. Emanating a live event from multiple servers simultaneously affords little real advantage, which limits the effectiveness of load balancers to on-demand content.

Splitters – Splitters are special servers placed into a tree-like hierarchy, where the root server splits a stream to multiple servers downstream. Each of these downstream splitters, in turn, further splits the stream for forwarding to yet another set of downstream servers. This pyramid nature of a splitter network suffers from numerous limitations. Splitter networks are static and topology-dependent, making it necessary to configure and manage them on an event-by-event basis. Multiple single points of failure exist along the tree, so if a single splitter fails, the entire downstream network fails as well. And splitters are generally one-way devices supporting only a single format with a single injection point. A separate splitter network must, therefore, be maintained for each broadcast format, which makes interfacing two or more into an Internet-wide federation of networks prohibitively complex. While splitting may have a role to play at the very edges of the network, this technology is not dependable or scalable enough for the backbone.

Quality of Service – Because streaming media demands that continuous streams be broadcast in real-time, numerous initiatives are attempting to overcome the best effort nature of today's Internet. This is especially important for streaming media traffic that employs the User Datagram Protocol (UDP), because UDP does not retransmit lost or damaged packets. Of course, streaming media is tolerant of some packet loss. It is intolerant, however, of delays in transmissions, known as latency, or variations in delay, known as jitter. Voice over IP (VoIP) exhibits a nearly identical

set of characteristics. The various Quality of Service (QoS) techniques being proposed for both VoIP and streaming media enable the Internet to treat different types of traffic differently. Examples include Differential Services (DiffServ), Class-Based Queuing (CBQ) and the Multi-Protocol Label Standard (MPLS). But none of these protocols does anything to increase the available bandwidth or eliminate the potential for redundant traffic when broadcasting streaming media traffic.

Satellite – A few new service providers are now offering supplemental backbone bandwidth for the Internet via satellite. Satellite is fundamentally a broadcast technology, and is therefore suitable for live events or the pushing of on-demand content out to the edges. Dishes at ISP points-of-presence receive the satellite broadcasts, then relay the content on to caches or servers, or directly to users. This new use for such a proven technology will likely only have a "supporting role" to play in Internet broadcasting because satellites are expensive and limited to one-way communications.

Even when the pieces just described are applied fully, the puzzle is only partially complete because it does not give the Internet the ability to broadcast a live event to millions of viewers who, by the very nature of a live events, are all watching exactly the same thing at the exactly same time — "flash crowds." It also doesn't give providers the ability to monetize their streams and make Internet broadcasting a profitable business proposition. What the industry needs is a capable and scalable end-to-end *architecture* that will finally equip the Internet with production-grade broadcasting capabilities.

4. A "Prime Time" Internet Broadcasting Architecture

This section lists the business and technical requirements that a viable Internet broadcasting design must meet, and describes an architectural approach that satisfies those requirements.

The Internet has become a victim of its own success. When contemplating the addition of even *more* applications atop an already overtaxed workload, it is essential to be sensitive to a few constraints. Wholesale changes — those that require "forklift upgrades" — are unacceptable. Not only are they disruptive, but they are often too expensive to justify. Therefore, any major new enabling technology must embrace every previous change that is now part of the Internet's configuration and culture.

The Fundamental Requirements of "Prime Time" Internet Broadcasting

Inktomi's quest for a robust and enduring architecture identified the following fundamental requirements that had not been totally satisfied by existing technologies or approaches:

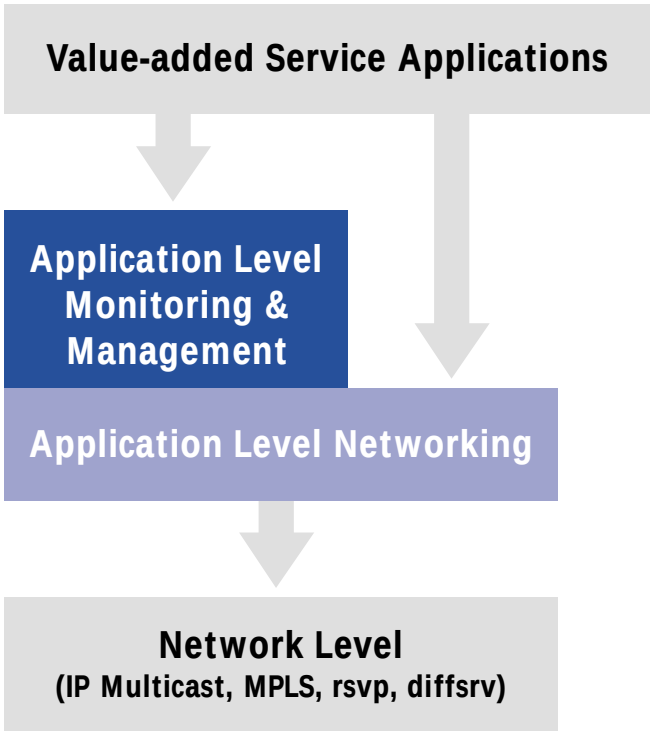
- The solution must be compatible with the underlying IP routing/switching infrastructure to make it commercially viable, and require no changes to any client/server applications, including edge-scattered caching. At the same time it should take full advantage of any hop-by-hop capabilities, such as IP Multicast, satellite links, segment-specific quality provisions, etc.
- The solution must be scalable to thousands of programs and millions of viewers without degradation in performance levels or quality, which requires minimizing the utilization of bandwidth and other network resources.
- The solution must be resilient and reliable with the ability to sustain quality by broadcasting around all limitations, faults and failures in any segment of the network — adapting automatically and dynamically. Such dependability would be needed for both consumer acceptance and eventual use in mission-critical business applications.
- The solution must be either agnostic or all-inclusive and extensible with respect to streaming media technologies, including all media player formats, and be similarly transparent to audience members.
- The solution must operate successfully in the open, federated Internet business model so that multiple service providers can deploy broadcast domains individually, then peer at the content level with others collectively for end-to-end coverage.
- The solution must satisfy the business requirements of broadcasting, including service level monitoring and control, the capture of overall ratings and audience response, local and customizable ad insertion, and flexible billing arrangements, such as subscriptions and pay-per-view.

For this reason, Inktomi chose a top-down architectural approach to Internet broadcasting.

To succeed, the architecture would need to support both live and on-demand streaming media, and any enabling technologies would need to be implemented entirely in software that could be layered virtually atop the existing federated infrastructure. The approach would also need to meet a demanding list of specific technical and business requirements to offer the industry an enduring solution (see sidebar on "The Fundamental Requirements of "Prime Time" Internet Broadcasting"). And with the *problems* understood, the ideal *solution* became rather apparent.

An Overlay Architecture for Internet Broadcasting

Inktomi developed an architecture that layers multicasting end-to-end across a routed internetwork at the application layer rather than the networking layer. An overlay architecture that resides on top of the existing IP-routed infrastructure and equipped with application-level multicasting makes Internet broadcasting affordable to deploy, operate, upgrade and expand. In addition, an overlay architecture approach is flexible and extensible, supporting evolving needs and a full spectrum of value-added potential, including the ability to "peer" up and down the delivery chain at the application layer. Lastly, an overlay architecture provides the reliability, quality and manageability necessary to the success of the Internet broadcasting business.



Architecture

Technically Elegant in its Simplicity

The broadcast overlay architecture is elegant in its simplicity. As an overlay architecture, the design is able to leverage the entire existing infrastructure to achieve a total Internet broadcasting solution. Routers continue to route and switches continue to switch just as they had before, completely unaware that many of the packets processed are part of a new category of applications. An overlay approach also allows the solution to be deployed incrementally in both intra- and inter-domain environments.

In addition, the overlay architecture is able to take full advantage of both tried and true capabilities and new enhancements. For example, if a provider chooses to deploy IP Multicast, they will realize a corresponding improvement in efficiency. Wherever Quality of Service (QoS) provisions are implemented, service providers will be able to offer Service Level Agreement (SLA) guarantees. And any hop with a satellite in its path will fit in seamlessly.

The use of application-level multicasting allows the overlay approach to achieve virtually unlimited performance and scale because it adds content awareness and intelligence end-to-end. In addition, with the right topology, the approach can obtain a fully meshed reliability.

The broadcast overlay approach not only interoperates with different redirection schemes, it can exploit their powerful capabilities. Redirection finds the "closest" source of the requested content — all the way from the nearest cache to the origin server — based on parameters like availability, proximity, current load, and permissions. Redirection is necessary for any intermediary or proxy device, such as a network cache or a load-balancing system, and is therefore a vital element of Internet broadcasting.

The overlay architecture is also bi-directional, which allows programming to be served up or "injected" anywhere, and gives the audience interactive privileges the producer, advertiser or service provider deems desirable. And except at its on- and off-ramps at the edges, the broadcast overlay architecture can be made fully agnostic with respect to streaming media encoding formats and technology.

Business Unusual

In addition to meeting all of the technical requirements of Internet broadcasting, the overlay approach also meets the many business needs of this opportunity, allowing providers to build solid profit models.

The overlay architecture is fully federated — just like the Internet itself — and application-level multicast permits peering of content within and across Internet domains. Just as importantly, the architecture permits top-to-bottom and end-to-end visibility and control across multi-domain environments. And along with these technical capabilities come the means to establish the business and financial arrangements among peering parties. Revenues can come from advertising, subscriptions, pay-per-view, tiered service levels, content preloading, reselling audience information and content acquisition services, as well as from the growing list of innovative, money-making models that characterize the new economy. For example, highly targeted advertising commands a premium price, as does specialty and customizable programming.

Finally, because an overlay-based design supports incremental deployment and expansion, service providers can employ a profitable "pay as you grow" approach to the Internet broadcasting business. Perhaps more than anything else, this single advantage will help assure the success of the Internet broadcasting industry — making it ready for "Prime Time."

5. The Media Distribution Network

This section introduces Inktomi's solution and describes how this innovative solution works end-to-end to make Internet broadcasting a profitable business.

Inktomi provides an end-to-end infrastructure solution for both live and on-demand Internet broadcasting. The solution enables service providers to build a Media Distribution Network that optimizes the provisioning of and provides full management control over streaming media content. Media Distribution Networks based on the Inktomi solution set help reduce costs and enable creation of new revenue-generating services that together make Internet broadcasting a profitable opportunity for all service providers.

Inktomi's solution consists of an extensible platform — based on an open architecture — and a complete companion product line. The product line lets any service provider begin building a successful media distribution business today. And as an extensible platform — implemented entirely in software — service providers get full investment protection as new capabilities are added. Inktomi's solution is the first to make Internet broadcasting a commercial reality —ready now for Prime Time levels of performance and profitability.

An Extensible Platform...

The solution builds on the overlay architecture outlined in the previous chapter with an extensible platform that has the following key elements:

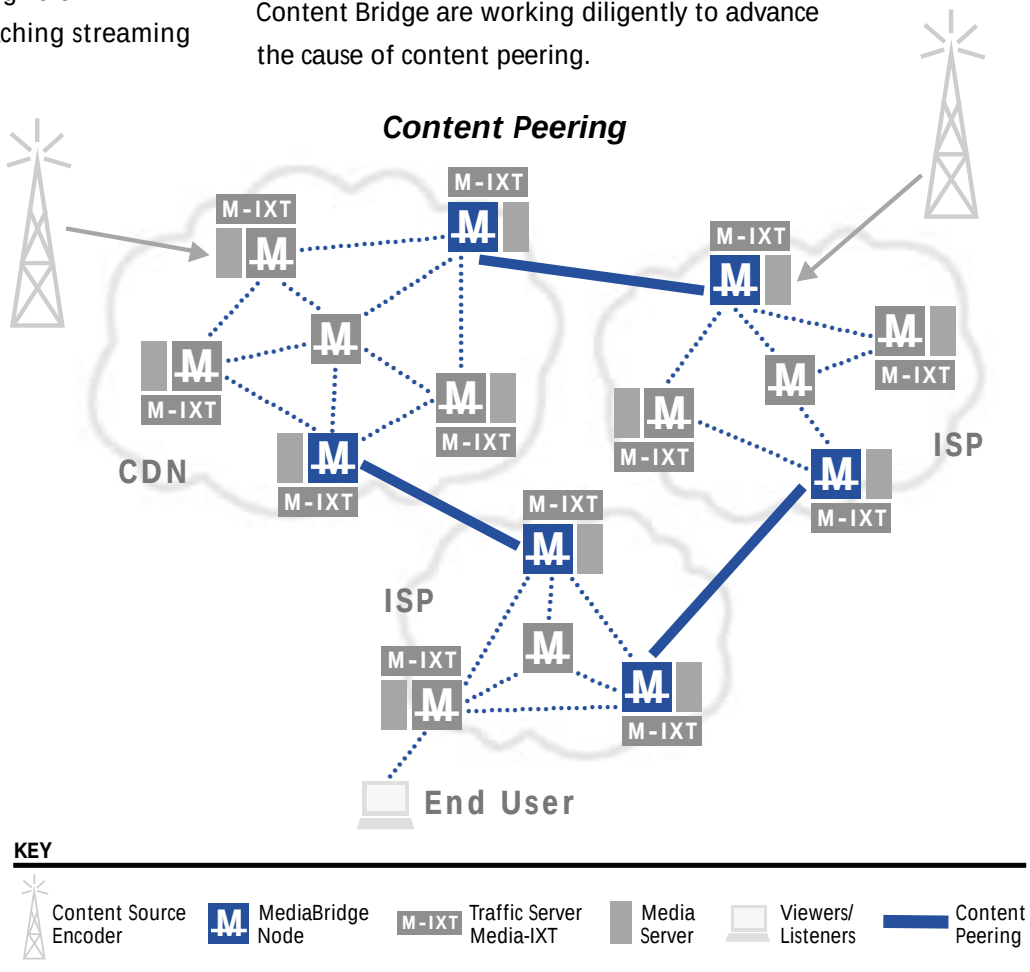
- An application-level multicast protocol capable of exploiting native IP multicast, satellite transmission and other forwarding options on a hop-by-hop basis
- Enables the integration of live and on-demand broadcast solutions with network caches and streaming media servers at the edges of the network
- A content peering capability based on application-level provisioning and monitoring that can work with any redirection scheme
- Real-time audience tracking, with historical archiving, that can scale to millions of viewers and listeners
- Centralized management control of broadcast quality and service levels, both within and across network domains

Each of the platform elements advances the state-of-the-art of Internet broadcasting, with the ***Application-level Multicast*** protocol serving as an enabling technology for the others. This innovative protocol routes media streams intelligently and

efficiently throughout the Media Distribution Network. Each node is able to make routing decisions adaptively and dynamically based on several parameters: service level and throughput requirements, the end-to-end topology, next-hop path characteristics and load, available alternative paths, and other variables. To ensure consistently high quality, the protocol can route around node or link failures, and can buffer and thin streams as necessary to alleviate link congestion — all automatically and in real-time based on policies established by the producer(s) and/or network service provider(s).

Integrated Network Caching, the second element of the platform, has an immediate and vital role to play for on-demand streaming media content, and could ultimately have a supporting role in broadcasts of live event. Caching streaming and rich media content at the edges of the network — close to the audience — treats users to a consistently superior experience with less latency and packet loss, which are the underlying causes of jerky or choppy audio and video. Caching also lets service providers reduce the total traffic load, thereby improving overall performance — and increasing overall profitability.

The ***Content Peering*** capability of a Media Distribution Network derives from the bi-directional nature of the application-level multicast protocol. Currently, service providers peer, or exchange packets, at the Network Layer — without regard to content — at both private peering points and at designated network access points. The platform builds on this well-established Internet function by extending it fully to the Application Layer, which allows service providers to exchange media streams and, potentially, other forms of content intelligently rather than blindly. While content peering is a technical feature of the platform, the real significance is found in its business potential. For as the various providers peer to exchange content, they will also be exchanging money in a variety of lucrative business arrangements. Which is why industry organizations like Inktomi's Content Bridge are working diligently to advance the cause of content peering.



Media Distribution

Audience Tracking, the fourth element of the extensible platform also addresses an important business need of Internet broadcasting: the ability to charge for subscriptions, pay-per-view, set advertising rates, and develop other revenue models. The tracking capability also allows content producers to gain insight into the performance of their media properties. Because the design is bi-directional, audience tracking can be implemented in simple agents that reside on servers at the edges of the network. A corresponding application is then able to accumulate and archive the collective statistics from all agents throughout the overly—all transparently to audience members, of course.

Finally, full ***Management Control*** of the Media Distribution Network and its content distribution functions is enabled by applications that exploit the inherent intelligence of application-level multicasting. The management tasks can be quite involved as the full spectrum of content is replicated, synchronized, provisioned, tracked, delivered and monetized across a global, multi-party network of edge-scattered caches and servers. Control of such an Internet broadcast overlay architecture must extend across content peering points, or these strategic nodes would become barriers to an end-to-end solution. In a Media Distribution Network, all service providers enjoy full management control over their respective domains and any peering arrangement provisions.

... And a Complete Product Line

Inktomi's extensible platform forms the foundation for the industry's first complete and manageable media distribution infrastructure. The end-to-end product line delivers measurable cost savings and enables revenue-generating services for content of all forms, including on-demand and live streaming media. The solution includes three components:

Core Content Distribution Infrastructure – MediaBridge™ software let service providers leverage the existing IP infrastructure to broadcast live on a large scale with the intelligence necessary to maximize quality and bandwidth efficiency.

Edge Server Infrastructure – MediaBridge ServerLinks and the Media-IXT™ software establish Inktomi's content distribution network at the edges in service provider POPs or all the way into the enterprise.

Content Management Infrastructure – The Broadcast Manager™ Suite, with CoreView™ and AudienceView™ software, and the Content Delivery Suite™ solution together supply the applications needed to monitor and control the entire broadcast network overlay and all the content it carries.

The ***MediaBridge nodes***, advanced application-level multicast routers, are the cornerstone product of the Media Distribution Network. Because MediaBridge nodes complement and enhance, rather than replace, existing networking infrastructure, they can be deployed in a profitable "pay as you grow" fashion. And because MediaBridge nodes are implemented entirely in software that operates on readily available — and inexpensive — hardware, they provide a potent, investment-protected foundation for the future.

MediaBridge software delivers the critical stream distribution functionality necessary to build a large-scale reliable broadcast network, including application-level multicasting, cut-through routing, stream regeneration, and intelligent stream thinning. MediaBridge nodes also handle AnyEdge™ stream injection and enable content peering. MediaBridge software provides agnostic support for any streaming media format, allowing a single overlay to handle all forms of content in the network's core.

MediaBridge ServerLinks provide the format-dependent on- and off-ramps for the Media Distribution Network. In addition, ServerLinks act as agents that transparently gather information about the audience. The agent captures statistics about audience size and location in the aggregate, and potentially down to a single member's programs, location, habits and tastes. Inktomi recognizes the power of this capability and is sensitive to audience privacy issues. As the industry resolves these issues, Inktomi will be in a position to add any features needed to support the emerging business models.

As a purely software-based product that conveniently co-resides on media servers at the edges of the network, ServerLink products are available for all three popular streaming media technologies:

RealNetworks RealSystem
Microsoft Windows Media
Apple QuickTime

MediaBridge ServerLinks fully leverage the agnostic nature of application-level multicasting. By contrast, most other streaming media solutions are "singular" in nature. That is, they require producers and service providers to deploy separate systems for each streaming media format desired. With Inktomi's design, multiple formats are supported economically, and new or enhanced formats are added easily.

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Traffic Server® Media-IXT™ is an industry-leading network cache system that improves bandwidth efficiency and throughput performance by caching frequently requested content at the edges of the network. As an extensible, software-only solution, Traffic Server Media-IXT lets service providers enhance quality while reducing total traffic load, which together serve to reduce subscriber churn and increase overall profitability. The product supports all three popular streaming media formats for simplified management, and scales readily in multi-tiered deployments. In addition, with Traffic Server platform's advanced coupled clustering technology, there is virtually no limit to its storage capacity. These and other features of the Traffic Server Media-IXT solution give service providers two important benefits: competitive differentiation and highly profitable new sources of revenue.

Monitor network health and audience response in real-time

Broadcast Manager Suite provides a complete end-to-end and top-to-bottom management solution for live and on-demand streaming media content. The two primary applications — *CoreView software* and *AudienceView software* — operate in real-time from ordinary Web browsers, and with appropriate authorization, let administrators watch both the network *and* the audience as the audience watches the broadcasts. The comprehensive nature of the Broadcast Manager Suite, combined with its policy-based and intuitive user interface, enable service providers to realize a greater return on their broadcast business investment. With the suite, providers can monitor network health and audience response, provide full network provisioning and monitoring of QoS and SLA guarantees, and review real-time and historically archived audience information for building profitable business models, such as advertising, subscription models and pay-per-view.

Content Delivery Suite solution manages the many tasks involved in replicating, distributing, tracking, synchronizing, provisioning and delivering content across a scalable network of Traffic Server Media-IXT network caches. The suite includes two core capabilities: Content Distributor to replicate and synchronize the content; and Content Manager to monitor, control and report on content distribution status and events in real-time. Content Distributor lets service

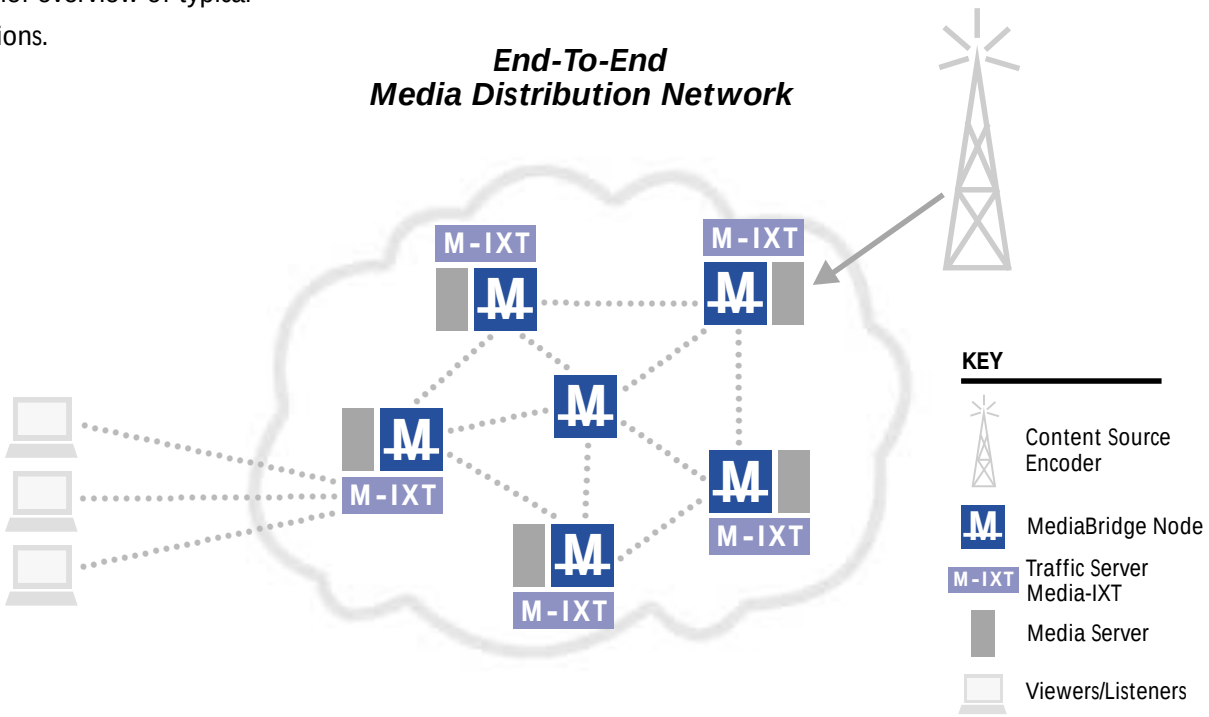
providers pre-load new or update existing streaming media content in advance of specific events or as part of an on-going business arrangement. Content Manager has a graphical user interface that makes it easy to define and schedule content distribution.

Putting Together the Pieces for a Worldwide Media Distribution Network

Although incremental deployment, either in an intra-domain or in a peered inter-domain environment, is a major advantage of a Media Distribution Network, it is best understood and appreciated as an end-to-end, global solution. This section provides just such a "big picture" perspective, and is followed by a brief overview of typical deployment options.

The end-to-end Media Distribution Network consists of three types of nodes deployed in broadcast POPs: Ingress, Transit and Egress. Media streams enter the Media Distribution Network at *Ingress* nodes, from ordinary streaming media servers through MediaBridge ServerLinks. The Ingress nodes are connected to one or more *Transit* nodes where topology-aware MediaBridge nodes forward the streams to adjacent nodes based on audience demand. Streams are delivered to audience members at *Egress* nodes through MediaBridge ServerLinks that interface to ordinary media servers, or to a Traffic Server Media-IXT network cache.

End-To-End Media Distribution Network

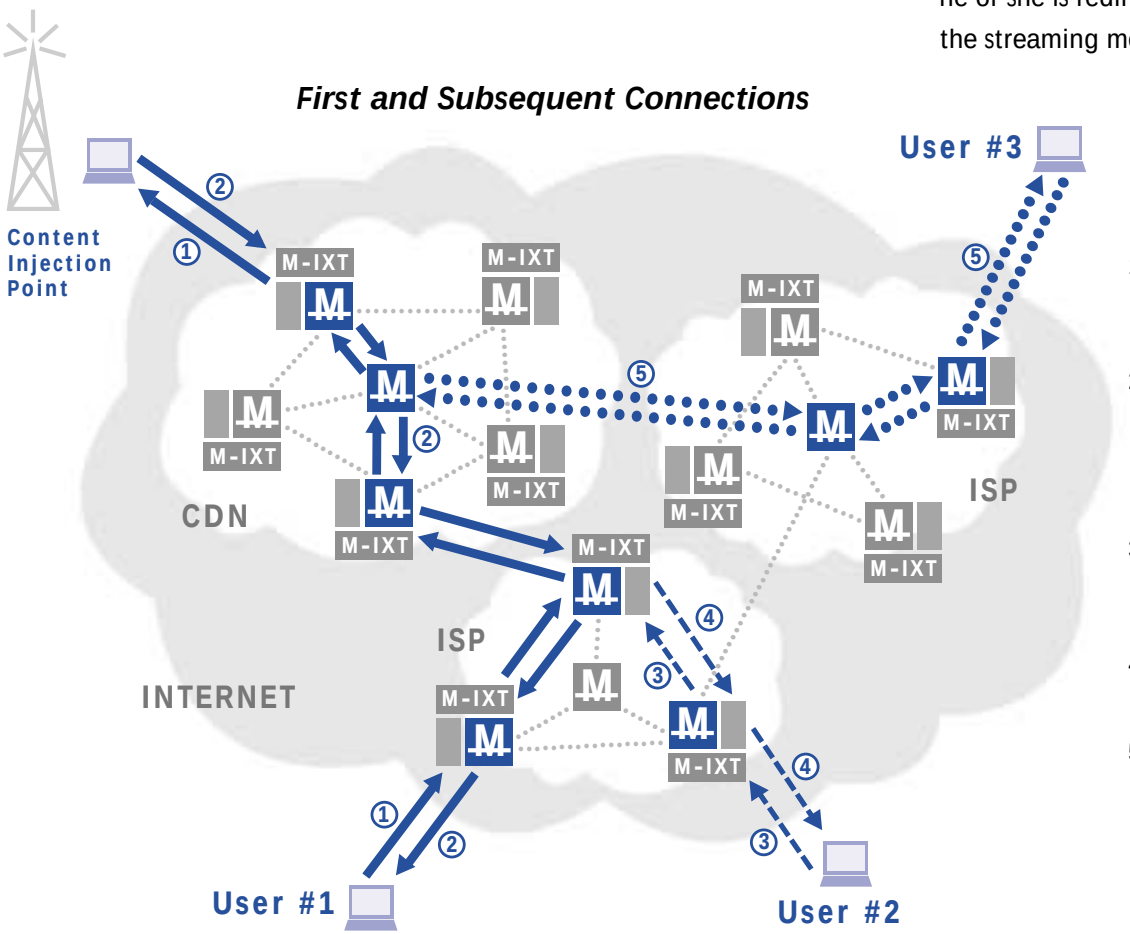


Media Distribution

The combination of a MediaBridge and a Traffic Server Media-IXT network cache is a powerful one in any Egress node because it handles both live and on-demand streaming media content. When a nearby user requests a program on-demand, for example, the Traffic Server Media-IXT solution checks to see if the content is in its cache already, and if that content is also current. If not present and current, the request is forwarded to the nearest server, or to the origin media server if necessary, and the new or "fresh" content is then cached to satisfy any and all future requests. By serving content from the edge, users enjoy a consistently superior experience based on a minimization of the latency and packet loss that cause streaming media quality to become unsatisfactory — and, ultimately, unacceptable.

To conserve bandwidth, the Media Distribution Network relies exclusively on audience demand to route streams end-to-end. A producer "injecting" a media stream is somewhat of a non-event until audience members start to "tune in." The act is analogous to posting content on a Web server, where it stays until someone requests it. When the first user requests the stream, he or she is redirected, transparently, back to the streaming media server at the Ingress

First and Subsequent Connections

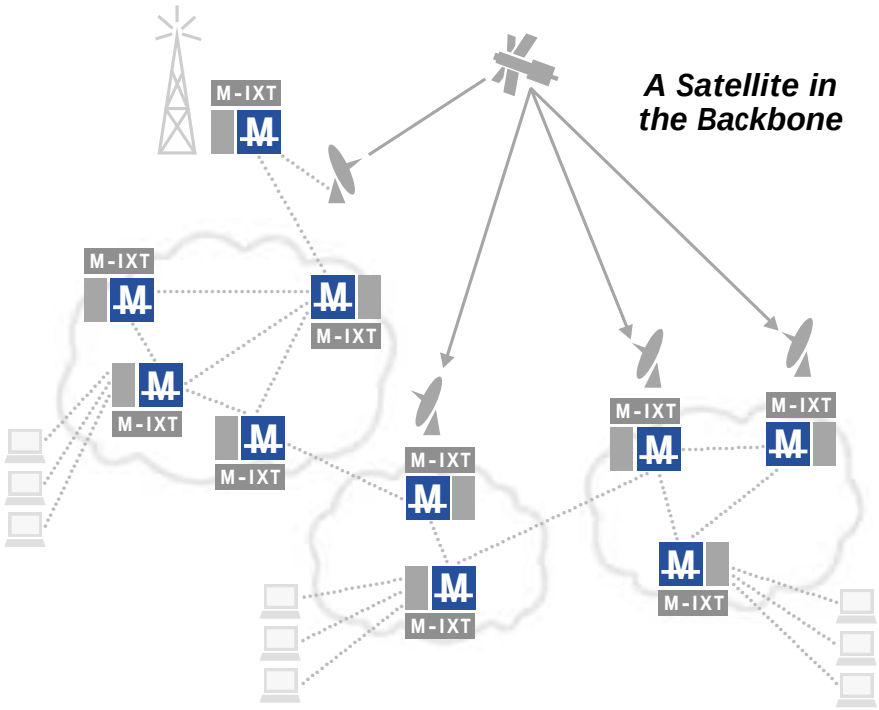


1. User #1 requests content, MediaBridge node determines content source and sends request via MDN to the source.
2. MediaBridge node at the injection point pulls content and sends it down the application-level multicast tree to the media servers. Streams fed from edge server to client.
3. Subsequent client requests are directed to the nearest MediaBridge node carrying the stream.
4. The requesting MediaBridge node pulls the content to its media server.
5. Subsequent user requests follow the same process.

node. The stream then flows from the Ingress node through intervening Transit nodes to the nearest Egress node. When subsequent users "tune in," the real power of the Media Distribution Network becomes apparent. Each is redirected to the "nearest" node where the stream is already available and not a single hop further. The resulting bandwidth savings are enormous because traffic patterns depend mostly on the *location* of audience members and are nearly independent of the *size* of the audience.

Now imagine not just one program but thousands of programs being broadcast to audiences numbering in the millions worldwide. Each Transit node is receiving and forwarding multiple media streams, probably on every virtual path to every adjacent node, whether of the Transit, Ingress or Egress variety. Yet on no inter-node path is a single stream duplicated. The entire overlay is under control because the application-level multicast protocol is both content-conscious and topology-aware — constantly. Nodes or paths can fail or become congested, and the Media Distribution Network automatically reconfigures its path selection to ensure that all users remain connected without disruption. And when the nodes or paths previously taken out of service recover, the Media Distribution Network once again goes through its virtual path optimization

The virtual paths among MediaBridge nodes take full advantage of any underlying capabilities, such as IP Multicast or QoS mechanisms, including DiffServ, MPLS or the Resource ReSerVation Protocol (RSVP). In this way, the Media Distribution Network fully optimizes bandwidth utilization and assures the best possible performance. The virtual paths can also be terrestrial or satellite. A satellite-based "multicast" network, for example, is able to reach a virtually unlimited number of Media Distribution Network broadcast POPs, which in turn further propagate the media streams. Fortunately, with a Media Distribution Network, this patchwork of networking technologies and topologies can be managed as a single broadcast channel.



Media Distribution

The bi-directional nature of the broadcast overlay architecture allows each node in a Media Distribution Network to perform double-duty as both on- and off-ramps. An Egress node also serves as an Ingress node if it happens to be where a producer chooses to inject streaming media content. Note, too, that an Ingress/Egress node is a superset of a Transit node. In other words, it also functions as a Transit node when it happens to be on the best available path in the Media Distribution Network. Such versatility helps demonstrate just how robust the Media Distribution Network architecture truly is.

Additionally, the Ingress/Egress nodes can be at the very edge of the network, in an access POP, or much closer to the core. The only requirement is that the network *beyond* the "edge" of the Media Distribution Network (established by the nearest Ingress/Egress node) will not be part of the broadcast overlay architecture, and will therefore need to rely on point-to-point unicast routing to serve up the streams to the audience.

Deploying — and Growing — a Media Distribution Network

One of the real strengths of the broadcast overlay architecture lies in its potential to be deployed incrementally — from the edge inward or from the core outward, or in some combination of the two directions — which permits a profitable pay-as-you-grow approach to Internet broadcasting.

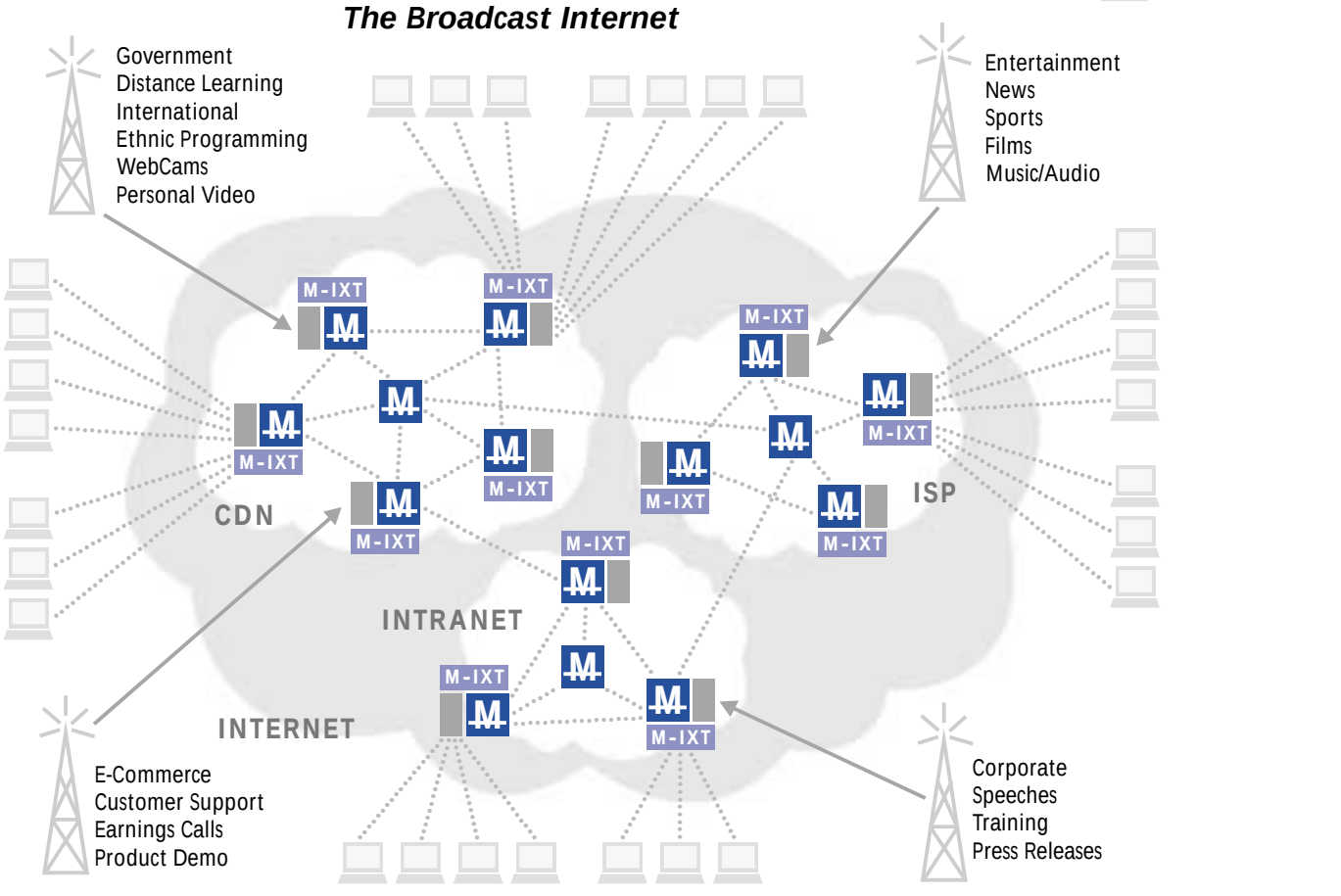
There are several locations in an existing IP network infrastructure that are obvious candidates for broadcast POPs functioning as a Ingress, Transit or Egress nodes. Typically, broadcast POPs are deployed at strategic Internet locations, such as network access points or other peering sites, co-location facilities, intra-domain hubs, data centers, access network headends and, potentially, enterprise networks.

The closer the broadcast POPs are to the audience, the greater the potential for bandwidth savings. Moreover, this makes planning the Media Distribution Network from the *outside in* the easier of the two approaches. Broadcast POPs at the Media Distribution Network's edge have Ingress/Egress MediaBridge nodes, ServerLinks and Traffic Server Media-IXT network caches. Initially, these should be located in or as close as possible to sites that either reach the audience or provide the program feeds — or both. Once the boundary of the Media Distribution Network is established by the edge broadcast POPs (Ingress/Egress nodes), the best sites for Transit nodes should become rather obvious.

Another important factor to consider is the extent of redundancy desired in the Transit overlay of the Media Distribution Network. A full mesh topology is probably unnecessary from the outset, but some use of alternate paths is warranted for two reasons. The first is quality of service and service levels for the streaming media audience. If a critical path is congested or

fails without a backup path, quality of service could degrade to an unacceptable level. The second reason is the potential for adverse impact on *other* users. If an application-level multicast path fails and the network suddenly becomes flooded with unicast media streams, everyone — not just the audience — will surely notice.

With the initial "Phase I" of a Media Distribution Network implemented, the Broadcast Manager Suite of tools can help identify changes you may want to make to the current Media Distribution Network. For example, network and audience data may reveal that an anticipated audience failed to materialize, or an unexpected one surfaced elsewhere. A portion of the backbone may have become somewhat congested as a result, or maybe very little traffic traverses a particular Transit node. Additionally, a new customer — content producer or access ISP — may sign up at either edge of the network. Another service provider may want to enter into a peering arrangement. None of these situations presents any real technical challenges. MediaBridge nodes can be installed easily and quickly without disruption to the Media Distribution Network itself or to any other network services.

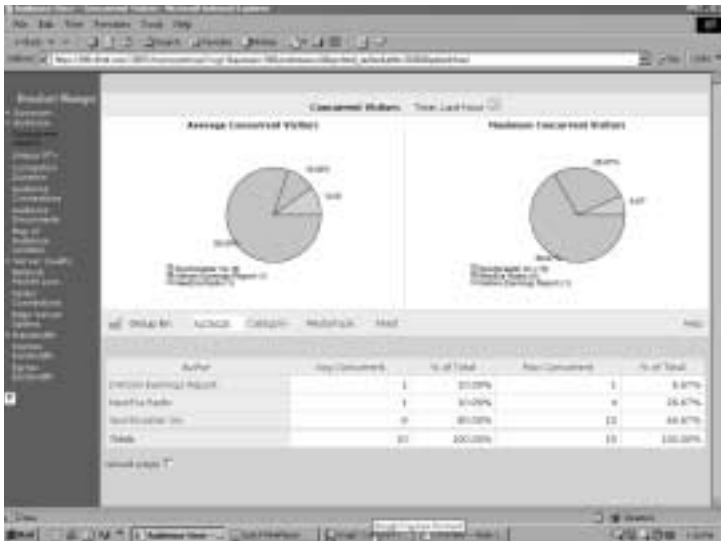


Media Distribution

Managing the Media Distribution Network End-to-End

Anyone who has attempted to broadcast a streaming media event on the Internet will truly appreciate the power of the Inktomi Broadcast Manager Suite. From broadcasting events to capturing audience statistics, the management tool set simplifies the many tasks involved in operating an Internet broadcasting business.

Broadcasting an event is straightforward with the solution's broadcast feed database. The database is how the Ingress node injection point(s) discover the location and characteristics of the media encoder supplying the stream. For example, a live broadcast might originate from a RealServer encoder at a radio station across an IP Multicast segment, or it could be posted on a Windows Media Technology server over an ISDN link. Either way, the streaming media content is now available for distribution live or on-demand.



AudienceView console lets you watch how many people are watching your broadcast

During the broadcast, a full set of real-time applications assist network managers with the tasks of monitoring, troubleshooting and refining traffic policies across the Media Distribution Network. The Broadcast Manager server runs as a daemon, typically on a dedicated host in a broadcast operations center. The daemon monitors the Media Distribution Network by communicating with software agents in the MediaBridge nodes and ServerLinks. The daemon server exports a Web-based user interface, compatible with any standard browser, that allows the broadcast operator to monitor the overall health of the network, examine application-level metrics, spot traffic problems, reconfigure links in real-time, track utilization over time, and so forth. This gives content producers and service providers an ability to generate revenue from targeted advertising, subscriptions, pay-per-view, tiered service levels, content preloading and acquisition services, and resale of audience information. These and other end-to-end capabilities make the Media Distribution Network the most manageable Internet broadcasting solution available.

The Media Distribution Network at Work

Internet broadcasting became a commercial reality with the advent of the Media Distribution Network from Inktomi. The Media Distribution Network empowers producers and service providers — and even enterprises — by delivering a total and enduring solution based on both a robust, end-to-end architecture and the enabling technologies needed to complete the Internet broadcast puzzle. The Media Distribution Network is already at work in the Internet.

Service providers report the following major benefits from using Inktomi's Media Distribution Network in their Internet broadcast business:

- The unprecedented ability to enable ***large-scale Internet broadcasting***. The Media Distribution Network scales in three dimensions: programs, audience and bandwidth. Users believe that a fully-deployed Media Distribution Network will support, as promised, thousands of events and programs to audiences numbering in the millions, all requesting streams encoded from 56 kbps to 1.5 Mbps.
- The potential to ***maximize profits*** on both the cost and revenue sides of the equation. Cost savings result immediately from the overlay approach that preserves the full investment in existing infrastructure, while the operational efficiencies derived from application-level multicasting result in a substantial reduction of bandwidth utilization. On the revenue side are new customers (at both ends of the broadcast), subscriber upgrades to broadband access and a completely new menu of highly differentiated, value-added services.
- The support for ***new and innovative business models*** both up and down the broadcast "feed chain" presents a wealth of opportunity — quite literally — based on features like content peering, ad insertion, audience tracking and others. The capability and flexibility found in the Media Distribution Network clears the path of any obstacles remaining in the way of the *business* of Internet broadcasting.
- The ***enhanced viewing experience*** delivered by Media Distribution Network's superior scalability, reliably and quality will help assure widespread adoption by making Internet broadcasting a satisfying success.

Professional Services

Inktomi offers an assortment of professional services to help in the design, implementation and integration of a Media Distribution Network. Available services include:

- Training
- Trial Quick Start
- Design & Planning
- Installation & Configuration
- System Integration
- Software Customization
- Project Management

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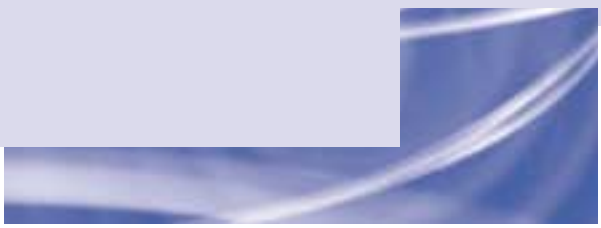
Media Distribution Network Advantage

Inktomi is the industry's first vendor to design and deliver a genuine and complete "Prime Time" Internet broadcasting solution for both live and on-demand streaming media. The Media Distribution Network affords numerous major advantages:

- Delivers a level of quality, reliability and scalability that is far superior to any other approach today, including those still on the "drawing board"
- Enhances the audience experience, which reduces churn, with full support for QoS/SLA performance guarantees and dynamic routing around network congestion or failures
- Utilizes efficient application-level multicasting to achieve unprecedented scalability by reducing bandwidth consumption in the range of 40% to 90% over existing methods
- Scales to support thousands of programs and millions of viewers concurrently
- Offers incremental and rapid deployment and peering with minimal integration headaches and no "forklift" upgrades
- Satisfies both the revenue-generating and cost-saving needs of all parties involved in the Internet broadcasting business
- Supports emerging business models based on audience response, subscriptions, pay-per-view, customized ad insertion and other value-added service options
- Gives both operators and broadcasters real-time stream-level visibility, policy-based control over QoS/SLA, and end-to-end provisioning, accounting and management
- Provides the only open, fully-manageable software-based solution available, allowing any and all service providers to get started immediately in the exciting Internet broadcasting market opportunity



About Inktomi Media Products

As the provider of the industry's only complete software-based infrastructure solution for Internet broadcasting, Inktomi Media Products enable both live and on-demand broadcasts to large-scale audiences reliably and with consistent quality. Inktomi Media Products help content distribution networks and service providers make profitable streaming media a reality. For enterprises, Inktomi Media Products enhance internal and external communications while conserving bandwidth and reducing overall network costs.

About Inktomi

Based in Foster City, Calif., Inktomi develops scalable infrastructure software that is essential to the Internet. Inktomi's business is divided into Network Products, comprised of industry leading solutions for network caching and content distribution; Media Products, including live and on-demand media broadcasting technologies; Search Solutions, providing search and content classification products and services; Commerce Engine, consisting of product search and merchandising services; and Wireless technologies. Inktomi customer and strategic partner base includes leading companies such as America Online, AT&T, British Telecommunications, Excite@Home, Intel, iWon.com, Merrill Lynch, Microsoft, Nokia, RealNetworks, Sun Microsystems, and Yahoo! The company has offices in North America, Asia and Europe. For more information visit <http://www.inktomi.com.

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